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DESIGN AND IMPLEMENTATION OF AN ACTIVE NOISE AND VIBRATION CONTROL SYSTEM BASED ON OMAP ARCHITECTURE

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With the rapid development of active control technology as an extremely effective way in noise reduction and vibration isolation, active control systems are increasingly dependent on their digit signal processing(DSP) performance to face the problems of high transmission speed, multi-channel operation, online algorithm call, real-time data display and storage. Therefore, in this paper, a new active noise and vibration control(ANVC) system is proposed and demonstrated in which the latest OMAP-L137 chip with both ARM and DSP cores has been employed in order to meet the total needs above. The whole system consists of signal acquisition module, active control module and data communication module. OMAP works as a signal processor unit in active control module, which has to send out the control signals after operating the input data collected from the vibrating object according to ANVC algorithms. With the benefits of its characteristics of embedded control system and its strong floating-point arithmetic ability, OMAP improves the system's stability, precision and speed when processing the input and output signals in a large number and real time. This ANVC system supports 32 channels, multi-sampling modes, AC algorithms updated online and real-time data display and storage via network communication based on TCP/IP. And its advantages has been shown in the examples of a noise reduction for air-duct and a vibration control for isolation platform, compared with their original systems using signal processor units without ARM. As a result, it not only performs better generalization in real applications and much better control abilities in real-time operating and large amount of data processing, but also affords the incomparable results in restraining low frequency vibration and random vibration. In conclusion, this high-speed & performance system has been verified to be advanced and practical as a common platform for ANVC applications.

Keywords: active noise and vibration control, control system, digital signal processing, embedded system

1. Introduction

Active noise control(ANC), active control of vibration, and active noise and vibration control(ANVC) have been proposed[1-3] and already implemented on a variety of platforms such as single-DSP[4], multi-DSP chip[5], FPGA[6], GPU[7] and so forth. However, with the rapid development of active control technology as an extremely effective way in noise reduction and vibration isolation, active control systems are increasingly dependent on their digit signal processing(DSP) performance to face the problems of high transmission speed, multi-channel operation, online algorithm call, real-time data display and storage.

Therefore, in this paper, a new active noise and vibration control system is proposed and demonstrated in which the latest OMAP-L137[8] chip with both ARM and DSP cores has been employed in order to meet the total needs above. The whole system consists of signal acquisition module, active control module and data communication module.

OMAP works as a signal processor unit in active control module, which has to send out the control signals after operating the input data collected from the vibrating object according to ANVC algorithms. With the benefits of its characteristics of embedded control system and its strong floating-point arithmetic ability, OMAP improves the system's stability, precision and speed when processing the input and output signals in a large number and real time. This ANVC system supports 32 channels(16 inputs and 16 outputs), multi-sampling modes, AC algorithms updated online and real-time data display and storage via network communication based on TCP/IP.

2. System structure

The active noise and vibration control system proposed is made up of a number of noise or vibrating sensors, speakers or actuators, active controller, and PC-based console as shown in the following Fig. 1. Active Controller contains signal acquisition, signal output, AC algorithm and network module.

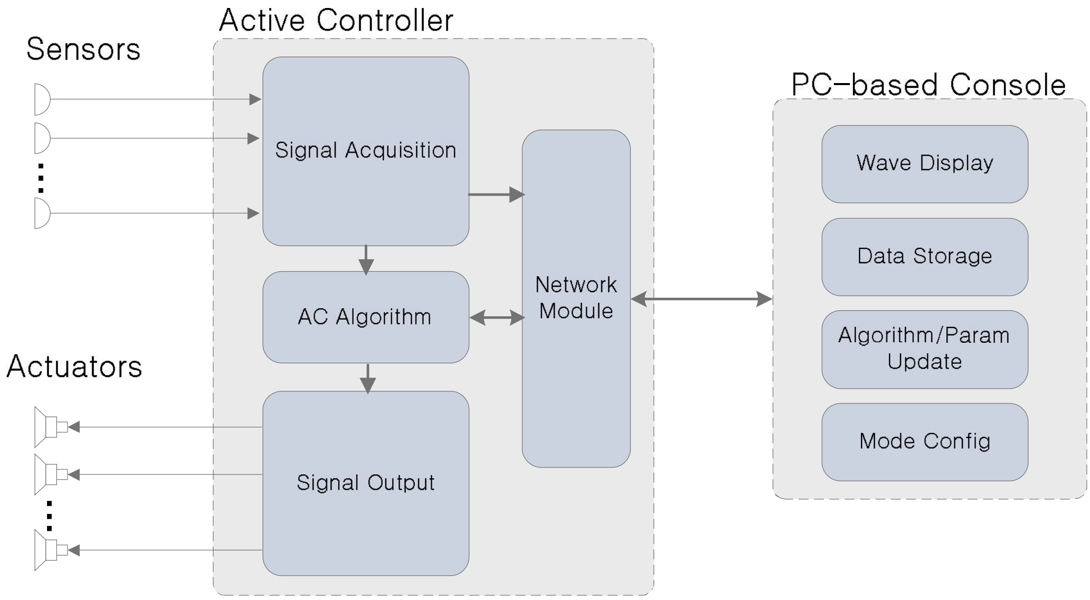

Figure 1:System structure of active noise and vibration control system.

The sensors like accelerometers, microphones, hydrophones or ultrasonic transducers can be used to acquire up to 16 channels of acoustic or vibrating analog signals respectively depending on different kinds of controlled object. The active controller obtains, preprocesses the analog signals and converts them into digital signals via signal acquisition module. On the one hand, the digital signals are forwarded to DSP algorithm which eventually drives up to 16 channels of speakers or actuators to accomplish noise reduction and vibration isolation. On the other hand, both input and output signal data is sent to PC-based console for real-time wave displaying, data storage and data analysis. Apart from receiving input and output digital signal via network communication based on TCP/IP, PC-based console is also able to configure the working mode of the active controller and update on-line DSP algorithm and some of DSP parameters.

3. Hardware design

The hardware design of the active noise and vibration control system shown in the following block diagram Fig. 2 consists of conditioning module, A/D module, D/A module, FPGA module, OMAP-L137 chip, and PC-based Console.

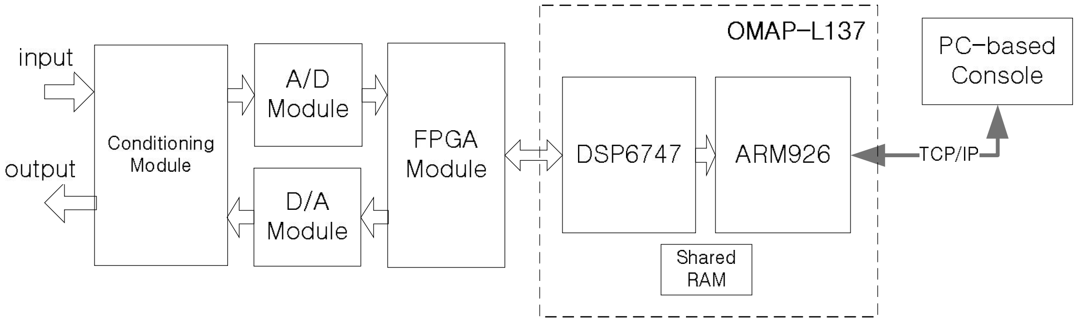

Figure 2:Hardware block diagram of active noise and vibration control system.

(1) For the part of the signal acquisition, the conditioning module obtains, amplifies and filters the input analog signals which immediately are forwarded to A/D module. FPGA Module controls A/D module to convert analog signals to digital signals and passes them to OMAP-L137.

(2) For the part of the signal output, OMAP-L137 gives control signals to FPGA which passes them through D/A module and conditioning module.

(3) For the part of data communication, input and output data is forwarded to ARM via shared RAM between DSP and ARM, and eventually forwarded to PC-based console via TCP/IP network.

4. Software design

4.1 Software Architecture

The software architecture of the active noise and vibration control system shown in the following block diagram Fig. 3 is composed of DSP, ARM and PC subsystem. For DSP subsystem, It includes DSP UBL(User Boot Loader), DSP APP(Application) which is for running DSP algorithm, and DSP IPS(Inter-Processor Signalling) which is for exchanging data using shared memory between DSP and ARM in Omap-L137. For ARM subsystem, It includes ARM OS(Operating System, linux2.6 applied), IPS Driver which is for exchanging data between DSP and ARM, and ARM APP which is for transmitting network data using TCP/IP protocol between ARM and PC-based console. For PC subsystem, it includes PC OS(windows-family OS applied), Socket DLL(Dynamic Linked Library) which is for transmitting network data between ARM and PC-based console, and Console APP which can also be replaced with a user-developed application.

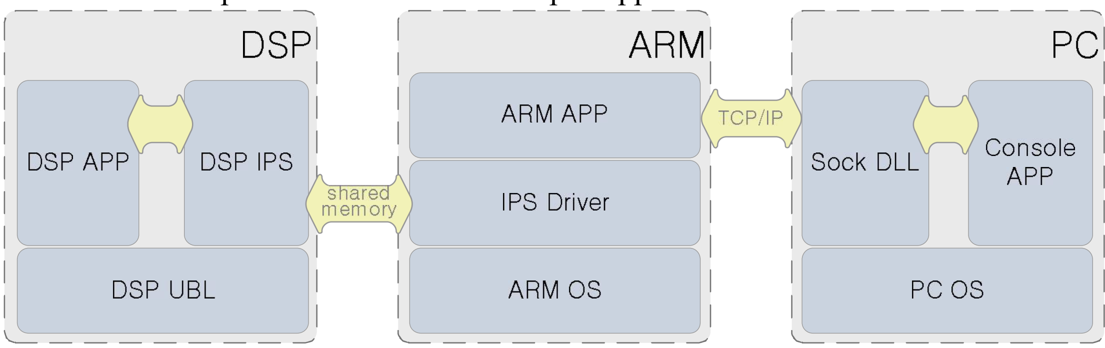

Figure 3:Software block diagram of active noise and vibration control system.

4.2 Starting procedure for active controller

The starting procedure for active controller is designed as the following Fig. 4 by virtue of the following considerations:

(1) DSP UBL starts ARM UBL instead of DSP RBL starting ARM UBL, because there are some versions of Omap-L137 like D800K003 and D800K005 which don't support DSP RBL's starting ARM UBL.

(2) DSP program is split into DSP UBL and DSP APP rather than one single integration for the sake of the capability of on-line update to DSP APP.

(3) Linux and yaffs(Yet Another Flash File System) file system.

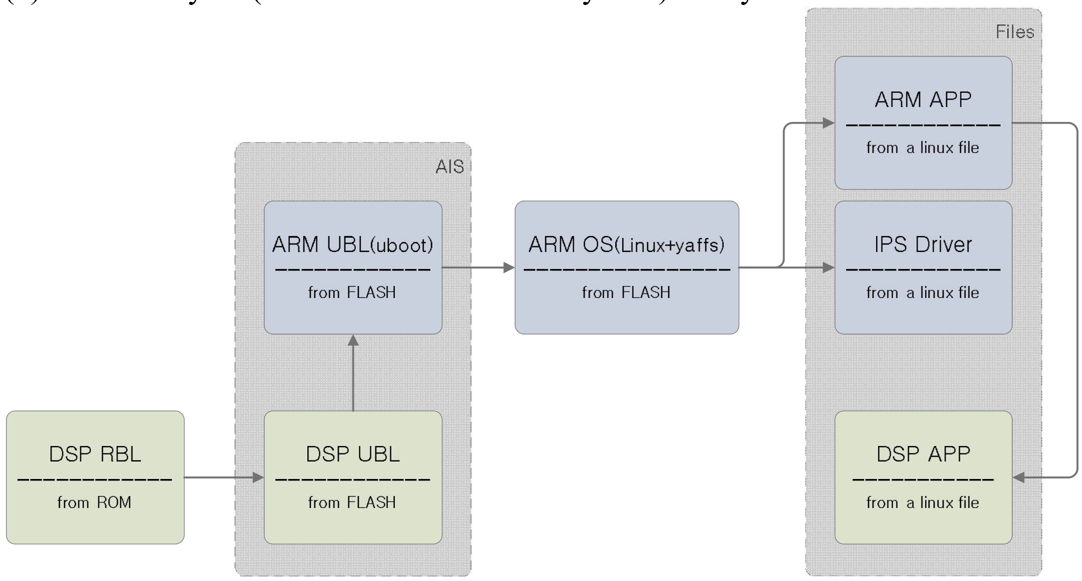

Figure 4:Starting procedure for active controller.

Upon Omap-L137 starts up, DSP RBL(ROM Boot Loader) loads DSP UBL into DSP memory and ARM UBL(Uboot applied) into ARM memory, and then starts DSP UBL which takes responsibility for starting ARM UBL. ARM UBL(Uboot applied) is used to load ARM OS(linux applied) and root file system in the format of yaffs, and then start linux which in turn loads and starts IPS Driver and ARM APP. Eventually ARM APP loads DSP APP into DSP memory and informs DSP UBL to start it.

Storage layout as followings: DSP RBL is lied in ROM. DSP UBL and ARM UBL is placed in Nand FLASH in the TI-designed AIS format. ARM OS is placed in Nand FLASH. And all the other programs are stored in the form of files under linux root file system.

4.3 Communication between DSP and ARM

Because Omap-L137 has two cores, DSP for high-speed computation and ARM for flexible and various interfaces, it is inevitable to figure out a communication solution between them. Here a fast-speed and stable design using in-chip interrupts and shared memory for the communication between DSP and ARM is given in the following Fig. 5. 128K bytes of shared memory are divided into two blocks of equal size respectively for two different transmitting directions, each block split into Ping and Pong buffer of equal size, 32K bytes. The interrupt SYSCFG_CHIPINT0 is configured for signalling ARM to fetch data from shared memory, the interrupt SYSCFG_CHIPINT3 for signalling DSP.

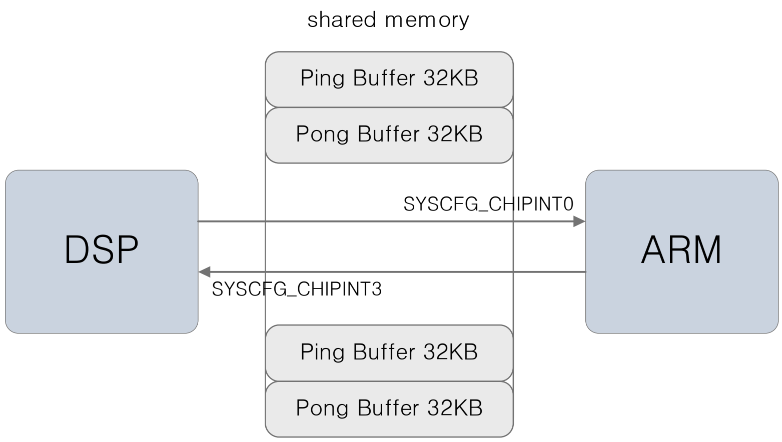

Figure 5:Communication between DSP and ARM.

5. Conclusion

The real system has been constructed and applied in the examples such as a noise reduction for air-duct and a vibration control for isolation platform illustrated in the following picture Fig. 6. It not only performs better generalization in real applications and much better control abilities in real-time operating and large amount of data processing, but also affords the incomparable results in restraining low frequency vibration and random vibration. In conclusion, this high-speed & performance system has been verified to be advanced and practical as a common platform for ANVC applications.

Figure 6:System applications in noise reduction for air-duct and vibration control for isolation platform.

REFERENCES

1 P. Lueg, Process of silencing sound oscillations, U.S. Patent 2043416, (1936).

2 C.R. Fuller, S.J. Elliott, and P.A. Nelson, Active Control of Vibration, San Diego, CA: Academic, (1996).

3 L.L. Beranek and I.L. Ver, Noise and Vibration Control Engineering: Principles and Applications, NewYork: Wiley, (1992)

4 Cheng-Yuan Chang, Efficient active noise controller using a fixed-point DSP, Signal Processing, **89**(5), 843-850 May, (2009)

5 Tomasz Zajac, Krzysztof Czyz, Active Noise Control System on multicore DSP, IFAC Proceedings Volumes, **43**(24), 40-43, (2010)

6 D. Shi, C. Shi, and W. Gan, A systolic FxLMS structure for implementation of feedforward active noise control on FPGA, Asia-Pacific Signal and Information Processing Association Annual Summit and Conference, 1-6, (2016)

7 J. Lorente, M. Ferrer, M. De Diego, and A. Gonzalez, GPU Implementation of Multichannel Adaptive Algorithms for Local Active Noise Control, IEEE/ACM Transactions on Audio, Speech, and Language Processing, **22**(11), 1624-1635, (2014)

8 OMAP-L137 Low-Power Application Processor, SPRS563A-SEPTEMBER, Texas Instrument (2008)